TABLE V.—*Excess of annual death rate per 100,000 from influenza and pneumonia (all forms), by weeks, Sept. 8 to Nov. 30, 1918, over that in corresponding week of median year (1910–1916) in 42 large cities.*[1]

City.	Sept. 14.	Sept. 21.	Sept. 28.	Oct. 5.	Oct. 12.	Oct. 19.	Oct. 26.	Nov. 2.	Nov. 9.	Nov. 16.	Nov. 23.	Nov. 30.
Albany, N. Y	37	......	31	29	2,018	5,025	8,535	7,087	2,300	800	41	488
Atlanta, Ga	110	......	15	82	666	1,972	2,471	849	633	499	402	643
Baltimore, Md	−37	−50	43	794	4,253	10,419	8,194	2,915	953	189	53	65
Birmingham, Ala	−23	−26	−33	322	1,493	2,770	3,369	2,095	1,061	1,056	990	1,694
Boston, Mass	188	1,634	5,015	7,925	6,680	3,765	1,350	753	343	143	172	156
Buffalo, N. Y	17	56	96	444	1,892	5,752	7,880	4,894	1,723	743	217	216
Cambridge, Mass	253	109	4,829	6,461	5,285	2,845	867	759	189	262	248	140
Chicago, Ill	−53	−50	79	728	1,988	4,105	4,620	2,801	1,316	600	305	223
Cincinnati, Ohio	− 1	−21	− 4	137	749	2,291	3,386	2,957	1,882	1,046	1,137	997
Cleveland, Ohio	−26	− 9	− 2	44	177	928	2,818	4,282	3,256	2,132	1,403	1,113
Columbus, Ohio	−28	40	83	170	579	1,613	2,623	2,084	1,057	721	860	1,315
Dayton, Ohio	33	− 9	23	132	1,155	5,248	5,352	4,463	2,535	688	45	359
Fall River, Mass	......	264	715	3,863	8,095	7,730	3,863	1,533	869	447	267	128
Grand Rapids, Mich	......	......	......	......	......	......	......	......	......	1,059	788	628
Indianapolis, Ind	− 6	44	111	356	745	2,210	1,968	1,402	926	735	967	1,653
Jersey City, N. J	−65	− 2	242	973	3,666	......	6,823	......	......	......	......	......
Kansas City, Mo	28	......	103	47	1,521	2,713	3,117	3,173	2,177	1,198	921	1,461
Los Angeles, Calif	36	−14	−42	70	576	1,144	2,625	3,435	2,759	2,664	1,688	1,405
Louisville, Ky	20	143	26	228	1,889	3,764	3,770	1,348	1,098	678	584	1,159
Lowell, Mass	−15	311	1,451	4,358	6,644	5,441	3,902	1,311	252	242	375	−73
Memphis, Tenn	......	......	......	......	2,624	6,042	5,479	2,254	......	392	402	−20
Milwaukee, Wis	......	− 4	91	108	711	1,215	1,915	1,328	971	675	427	873
Minneapolis, Minn	−19	......	97	120	592	1,280	1,963	1,541	1,191	1,151	575	490
Nashville, Tenn	21	......	45	124	5,538	8,327	5,420	2,206	2,135	446	464	747
Newark, N. J	......	9	27	565	2,205	4,799	5,123	4,444	2,014	1,200	687	501
New Haven, Conn	......	−32	401	1,102	2,479	4,906	6,033	5,519	2,615	1,459	503	621
New Orleans, La	−23	......	−54	294	1,852	8,385	9,156	4,368	1,957	822	281	356
New York, N. Y	−20	11	93	629	2,010	4,107	5,091	4,259	2,122	885	473	223
Oakland, Calif	19	......	−32	− 9	354	936	3,271	5,679	3,728	1,603	811	164
Omaha, Nebr	−53	......	−26	121	1,887	4,547	4,164	2,618	......	1,245	929	790
Philadelphia, Pa	− 3	31	157	2,014	7,716	13,515	8,841	3,448	986	350	154	106
Pittsburgh, Pa	−18	14	146	430	805	3,197	4,816	5,269	6,726	4,369	3,070	2,293
Providence, R. I	3	115	348	1,868	3,587	4,948	4,210	2,558	1,162	575	502	290
Richmond, Va	66	31	57	1,246	4,149	6,275	4,025	2,166	760	586	243	577
Rochester, N. Y	−42	−49	61	32	612	1,902	4,077	3,989	1,914	886	646	585
St. Louis, Mo	15	17	57	82	478	1,135	1,436	1,581	1,378	1,358	1,089	1,374
St. Paul, Minn	21	......	12	−32	1,177	1,458	1,091	2,000	2,141	2,664	1,795	1,306
San Francisco, Calif	−28	53	55	50	92	1,300	5,899	7,927	4,397	2,041	857	466
Syracuse, N. Y	......	......	1,150	4,410	6,991	8,085	4,425	2,088	784	610	83	76
Toledo, Ohio	−20	......	30	−13	101	886	2,642	2,168	1,575	769	690	421
Washington, D. C	68	52	373	2,174	6,257	7,989	4,955	2,240	584	394	312	364
Worcester, Mass	141	438	2,955	5,891	6,813	4,702	2,465	1,662	......	272	744	462

[1] The weekly rates for the median year in the period 1910–1916 have been approximated by plotting the rate for the median year for each month (thus affording a rough "normal" seasonal curve) for each city, and then by reading from the curve the indicated median rate at the mid-point for each week. The excess has been found by subtracting this median rate from the actual rate for each week in 1918. When the difference is "minus" it is so indicated.

THE EFFICIENCY OF CERTAIN DEVICES USED FOR THE PROTECTION OF SAND BLASTERS AGAINST THE DUST HAZARD.

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The Dust Problem in Sand Blasting.

In most industrial plants the protection of the worker against the hazard of industrial dusts can be best accomplished by keeping the dust content of the air of the workroom itself down to a reasonable level. The control of the dust in the workroom air is effected, in such cases, either by substituting wet processes for dry grinding procedures and the like, by carrying on dust-producing operations in inclosed spaces, or by equipping such devices as emery wheels and buffing wheels with exhaust hoods and suction fans. The success which may be attained by the last of these three means was

discussed in a paper published in Public Health Reports for March 7, 1919, pages 427–449.

In other industrial processes, as in certain packing operations, in marble and granite working, and in the sand blasting of large castings, it is impossible to render the general air of the work place sufficiently free from dust to avoid danger of injury to the respiratory tract of the worker. In such cases as this, protection against the dust hazard can only be attained by the wearing of helmets, masks, or respirators, which will either filter out the dust particles from the air before it is drawn into the respiratory tract, or exclude the surrounding air more or less completely from the nose and mouth and supply pure air for breathing from some other source. It is difficult to accomplish these ends without interfering seriously with the comfort of the person wearing the helmet or respirator. A large number of devices designed to protect the worker against dust are on the market, but the discomfort produced in practice prevents the use of many of them; while those of simpler construction, which are less objectionable to the worker, are frequently of more than doubtful efficiency.

It seems essential as a prerequisite for the standardization of protective measures in this field to determine first what results may be actually accomplished in the way of dust control by different types of masks, helmets, and respirators, and then to weigh carefully the efficiency of each piece of apparatus as balanced against the discomfort which may reasonably be expected to militate against its actual use.

Previous Studies of the Efficiency of Helmets and Respirators Designed for the Protection of the Worker in Dusty Trades.

The most extensive previous studies of this subject which have come to our attention were made in the Hygienic Institute of the University of Berlin, and are to be found in volume 68 of the Zeitschrift für Hygiene for 1911. In the first of these papers Kobrak describes a special form of mask designed especially for protection against infectious droplets and dust, and in the second paper Schablowski reports an extensive series of studies on the efficiency of various types of respirators used for protection against industrial dusts. Both observers used bacterial spores as a measure of the purifying effect exerted by the devices studied. In Schablowski's experiments the industrial dusts studied (cotton, cement, basic slag, and rouge) were intimately mixed with a suspension of saprophytic spores, redried and blown into the air of an experimental chamber. A person equipped with one of the protective devices under examination, and a control individual with no such protection, entered the chamber, the noses of both being plugged with sterile cotton in amount sufficient to filter out the dust contained in the air without

interfering too seriously with respiration. At the close of the experiment the cotton was washed in sterile water, gelatin plates were made, and the percentage removal of bacterial spores determined by comparing the count from the cotton in the nose of the unprotected individual with that in the nose of the individual wearing the mask or respirator. It was assumed that the removal of bacterial spores would correspond with the removal of the dust particles with which they were mingled. In a few cases control studies were made by direct chemical determinations of the amount of rouge collected by the cotton filters in the nose.

A large number of different types of respirators and helmets were studied by Schablowski, using the methods outlined above. The removal effected varied from 11 to 89 per cent, the latter result being attained by the use of the Kobrak mask with *Moellertuch* as a filtering material. The method used in these studies is ingenious, but the opportunities for experimental errors in the bacteriological technique involved are very considerable, and the assumption that the efficiency of dust removal will vary with the removal of bacterial spores mixed with the dust is a somewhat doubtful one.

A more recent study of the efficiency of respirators is reported by the Miners' Phthisis Prevention Committee of South Africa in its General Report issued in 1916 (pp. 28–30). Nine types of respirators were studied, a sugar filter being used to determine the respective dust content of normal mine air, and of similar air passed through the respirators. Before blasting, the mine air contained from 1 to 10 milligrams of dust per cubic meter, and the same air after passing the various respirators contained from 0.5 to 1.3 milligrams. The removal effected by the various types of respirators varied between 30 and 88 per cent. After blasting, the mine air contained from 41 to 63 milligrams of dust per cubic meter, and the dust after passing the respirators contained from 13 to 63 milligrams. The removal effected varied from zero to 77 per cent. The results obtained before and after blasting with the same respirator vary widely. For example, one type of respirator effected a 75 per cent removal before blasting and produced no reduction at all after blasting. In view of these wide differences it seems probable that local variations in the dust content of the mine air must have been considerable.

Studies made in England and in this country during the war have made contributions of the first importance to the art of constructing efficient and practical respirators for protection against toxic gases. The results obtained are not, however, directly applicable to the somewhat different problem of dealing with industrial dusts.

It seems most important to obtain more detailed and accurate information in regard to the actual efficiency of respirators of the various types actually used in industrial plants in the United States,

and the Palmer apparatus used by the writers in earlier investigations offers an excellent means of conducting investigations of this kind. We therefore welcomed the opportunity to undertake a study of this sort in connection with problems that had arisen in the sand-blasting department of a large automobile factory in Connecticut.

Description of Installation and of Methods used in the Present Study.

Description of the sand-blasting room in which the present study was conducted.—In the plant where the present study was conducted, the sand blast is used for cleaning and preparing the metal parts of automobiles for subsequent operations. The equipment in the workroom where this process is carried on consists of three sand-blasting cabinets, two horizontal sand-blasting barrels, each 36 by 46 inches, and one small inclined spindle tumbling barrel. The sand-blasting barrels and the tumbling barrel present no problems in dust control, for the sand-blasting barrels require attention only while being filled and emptied, remaining closed during actual operation, and are equipped with an exhaust system by means of which the residual dust in the air of the barrel is exhausted; while the tumbling barrel is used only to polish and clean small metal parts by means of sawdust.

The sand-blasting cabinets with which our study deals are each 8.5 feet wide, 11.5 feet long, and 8.5 feet high, and are constructed of 16-gauge sheet iron, with wire glass roofs. Each cabinet is provided with four 12 by 16 inch openings in the roof for the admission of fresh air and with a 45-inch planing mill fan which exhausts air through a perforated floor.

The general method of operation will be made clear by reference to Figure I. The sand from the sand-blast machine is forced by compressed air under 20 to 25 pounds pressure through the hose and nozzle against the material to be treated. The sand after use falls through the perforated floor into hoppers (4 for each cabinet) in a pit beneath, from which it is carried by a 45-inch planing mill fan into a separator (A). This separator takes out and returns to the sand-blast machine any sand that is large enough to be used again. The exhaust air with the remaining finer sand then passes through the fan and into a roof separator (B), where the residual sand is finally deposited, the sand returning by gravity to a sand can in the room below, while the air escapes to the atmosphere. One fan handles the sand from the hoppers of all three of the cabinets. The hoppers below the sand-blast chamber are not in structural connection with it, and a certain amount of sand and dust finds its way out into the pit in which the hoppers are located.

The finer material in the air of this pit is exhausted by another 45-inch planing mill fan and carried to an independent roof separator (C). One of these fans is provided for each of the three pits. The fan serving the hoppers and the three fans serving the pits all cooperate in producing a strong down draft through the perforated floors of the cabinets. The sand from separator A being fairly coarse is used again in the cabinet from which it came. The sand

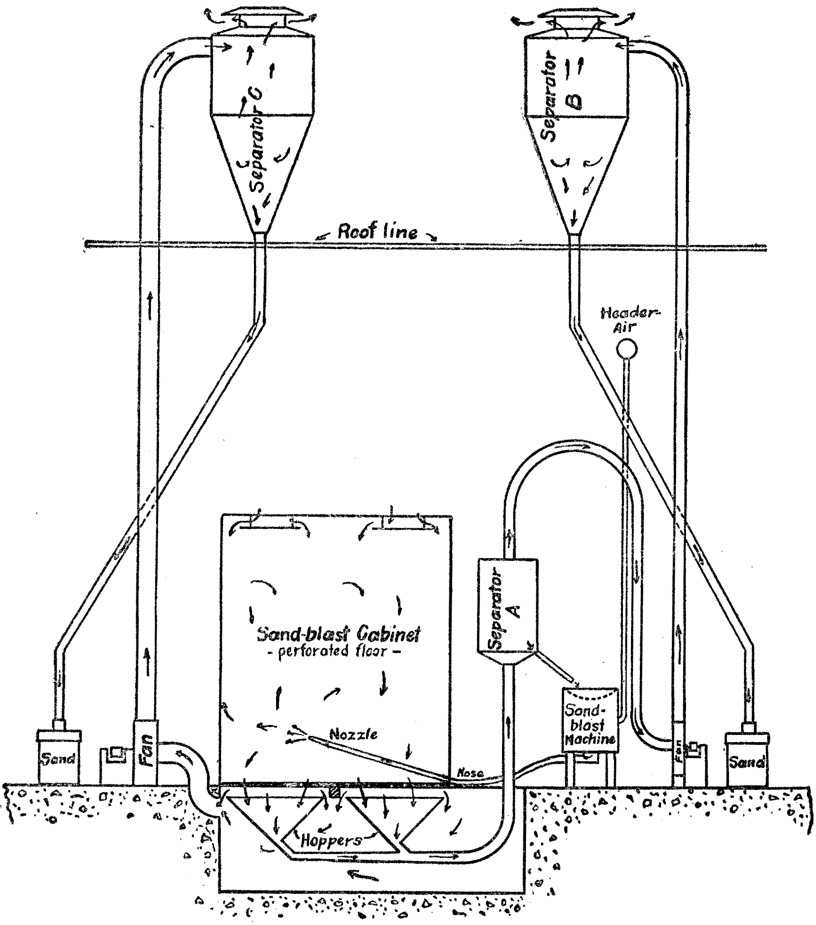

FIGURE 1.—Schematic layout of unit sandblasting installation showing cycle of sand and air.

from separator B is finer and is used in special work. The material which collects in separator C is too fine to be of any value and is discarded.

The sand-blast operators in this plant are provided with respirators of the ordinary "muzzle" type with a rubber body fitting over mouth and nose, an air filter, composed of two layers of muslin cloth having about 75 meshes to the inch, and a piece of sponge

Public Health Reports, Vol. 35, No. 10, March 5, 1920.

Fig. 2.—Worker equipped with respirator.

Public Health Reports, Vol. 35, No. 10, March 5, 1920.

Fig. 3.—Worker equipped with respirator and helmet.

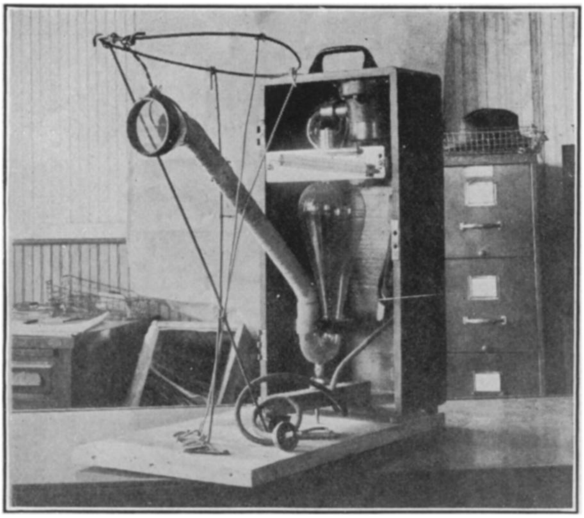

Fig. 4.—Sampling apparatus as used for determinging dust content of normal cabinet air.

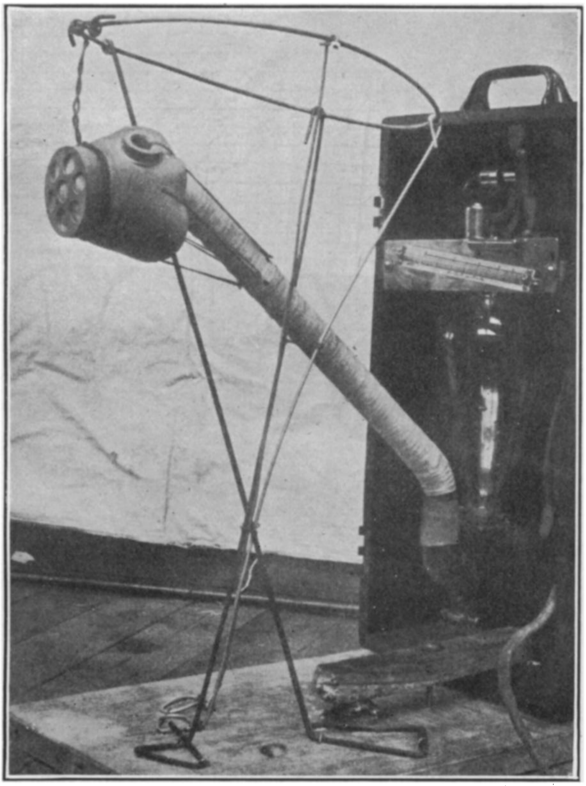

Fig. 5.—Sampling apparatus as used for determining the efficiency of the respirator alone.

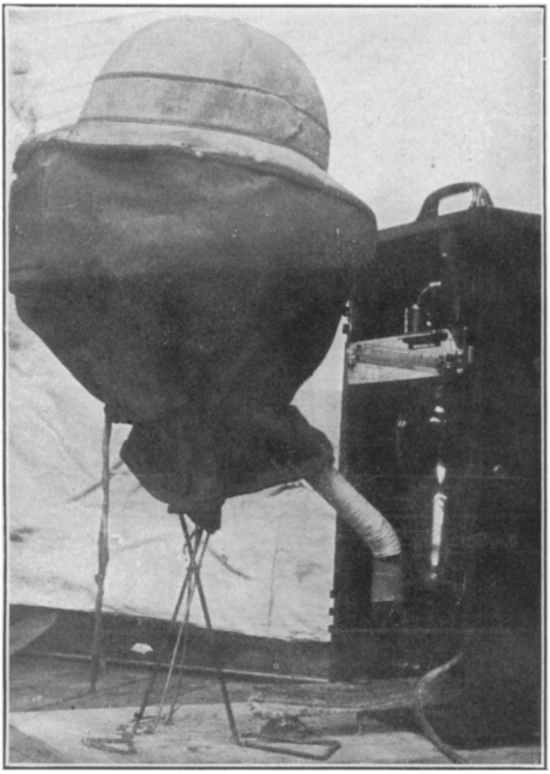

Fig. 6.—Sampling apparatus as used for determining the efficiency of the helmet.

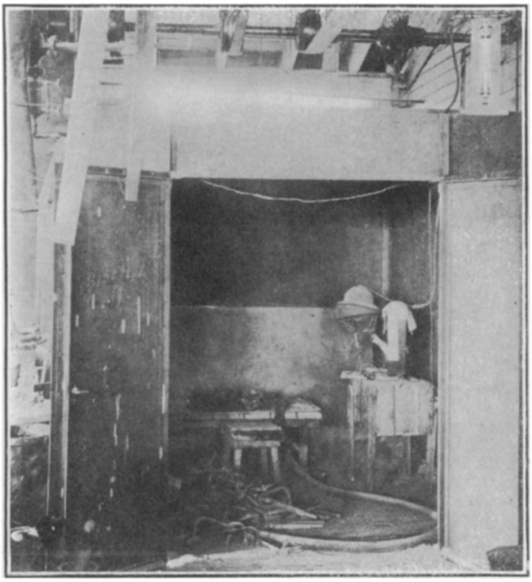

Fig. 7.—General view of sandblast cabinet, showing apparatus ready for sampling dust. The flow meter is shown at the top of the cabinet on the right.

about $2\frac{1}{2}$ by 3 by 1 inch, and fitted with an air outlet valve. They are also supplied with helmets made of cloth-covered cardboard, provided in front with a 3 by $4\frac{1}{2}$ inch window of 40-mesh wire gauze through which the operator may see, and provided also with an inlet tube on top for fresh-air supply. The helmet is fitted with a string by means of which the apron or lower portion may be drawn tightly around the neck, thus making an air-tight covering with the exception of the wire gauze-covered portion in front.

In using these protective devices the operator as a rule first places a handkerchief over his nose and mouth, tying it in a knot at the back of the head, then places the respirator in position, and finally puts on the helmet. The workers do not draw the string in the helmet taut, but as a rule allow the apron portion of the helmet to come to the shoulders. Figures 2 and 3 show the respirator and helmet as in ordinary use. The workmen do not make use of the air inlet at the top of the helmet, intended to be connected with a fresh-air supply line, for the reason that the fresh-air supply as drawn from the general supply air compressor is grossly contaminated with oil, which produces a very disagreeable odor when it is blown into the helmet in large quantities. Furthermore, it is difficult by means of the valves as at present installed to control the quantity of air supplied to the helmet; and, lastly, the fresh-air line enters the cabinet at one side, so that the length of unsupported hose necessary when working in the center of the chamber creates an uncomfortable drag on the worker's head.

Methods of study used in the present investigation.—Our immediate object was to determine the efficacy of the respirator and helmet used in the plant under observation, and if it was found, as was to be expected, inadequate, to determine the modifications in construction or operation necessary to secure a satisfactory degree of protection.

For collecting the dust samples we used the Palmer water-spray apparatus which we have found so satisfactory in our previous investigations. (Public Health Reports, Mar. 7, 1919, pp. 427-449.) The sampler was set up on a table in the sand-blast cabinet at about the height of the worker's head, while work was in progress as usual. The apparatus was protected against the direct blast of the sand by a covering of heavy wrapping paper. To the air inlet was attached a sampling tube 1 inch in diameter and 17 inches long, terminating in a funnel-shaped opening 3 inches in diameter. With the funnel open we obtained samples of the normal air of the cabinet (Fig. 4) and with the respirator held in position over the end of the funnel by means of rubber bands we determined the filtering effect of this device (Fig. 5). In testing the efficacy of the helmet the funnel, with or without the respirator, could be placed inside the helmet, which was supported on a specially constructed wire frame (Fig. 6).

In our later studies air was supplied to the inside of the helmet through the opening at the top designed for such a fresh-air supply. We used the air supplied to the cabinet for this purpose, passing it through a piece of 1-inch glass tubing with a constriction at its center and provided with a U tube, one branch of which joined the main horizontal tube on each side of the constriction. The effect of this constriction was increased by inserting orifices made up of short pieces of glass tubing in the constricted section and the flow of air was measured by the difference in level between the liquid in the two arms of the U tube. This type of flow meter was made use of in the investigations of the Chemical Warfare Service of the Army.[1] It was carefully calibrated in the laboratory against a gas meter of known accuracy, care being exercised not to use such volumes of air as would bring the air flow into the turbulent range and hence make the calibration inaccurate.

The methods of weighing and counting the dust particles collected were the usual ones recommended in the final report of the Committee on Standard Methods for the Examination of Air, American can Public Health Association (American Journal of Public Health, Vol. VII, No. 1), and need not be described in detail here. Each sample of dust was obtained by aspirating 40 cubic feet of air through our apparatus at a rate of 2 cubic feet per minute.

Results of the Present Study.

Normal dust content of the air of the sand-blast cabinet.—Ten different dust samples of the normal air in the cabinet during the process of sandblasting were collected on eight different occasions, and the results are presented in Table I. In this and subsequent tables the number of particles of dust per cubic foot of air is divided into two groups, those one-half standard unit in size and over being called "1 standard unit particles," while all those below one-half standard unit down to the limit of visibility under a magnification of 84 diameters are called "one-fourth standard unit particles." A standard unit is equal to an area 0.02 millimeters square, so that the "one-fourth standard unit particles" class includes all those particles having dimensions less than 10 by 20 microns.

The results presented in Table I show on the whole a considerable degree of uniformity, considering the variations in dust content one might expect in a process of this kind. The one-fourth standard unit particles (which are the ones of chief sanitary significance) varied between 15 and 82 million per cubic foot of air, and averaged 60,880,000. The weights varied between 12 and 119 milligrams per cubic foot of air, and averaged 55.29 milligrams.

[1] A. F. Benton, Gas Flow Meters for Small Rates of Flow: Jour. Ind. and Eng. Chem. *11*, 623-9 (1919).

TABLE I.—*Dust content of air in sand-blasting cabinet.*

Sample No.	Number of dust particles per cubic foot of air.		Weight of total dust mgs. per cubic foot of air.
	1 standard unit.	¼ standard unit.	
7021	4,280,000	68,600,000	87.30
7091	2,370,000	73,500,000	119.80
7092	1,500,000	67,500,000	65.00
7093	1,560,000	76,000,000	50.60
7253	1,025,000	29,200,000	12.43
8064	4,000,000	82,000,000	27.20
8265	2,266,000	37,000,000	18.53
8284	467,000	15,000,000	37.95
9034	4,000,000	80,000,000	53.70
9054	10,900,000	80,000,000	80.40
Average	3,236,000	60,880,000	55.29

These figures, so far as we are aware, represent the first quantitative determinations of the actual extent of the dust hazard in sand blasting. As compared with results for other industries (summarized in a paper published in Public Health Reports for May 30, 1919, pp. 1171-1187) they show weights far in excess of those previously reported. In earlier studies, weights have generally been reported in milligrams per *hundred* cubic feet of air, and the highest figures with which we are familiar are 218 milligrams per 100 cubic feet found by Miller and Smyth in a cement mill, and 780 milligrams per 100 cubic feet found by Winslow, Greenburg, and Greenberg in an abrasive factory. Our sand-blast figures (over 5,500 milligrams per *hundred* cubic feet of air) are of almost another order of magnitude.

The enormous weight of dust present in the air of the sand blasting cabinet is, however, chiefly due to the large particles of sand present (which appear in our 1 standard unit count column). These large particles are of no particular significance in connection with respiratory disease since, as the South African investigators have shown, it is the particles below 10 microns in diameter which actually enter the lungs and produce fibrotic changes. The ¼ standard unit particles in the air of the sand-blast cabinet (60,880,000 per cubic foot) may be compared with 6,790,000 found by Miller and Smyth in the cement mill, and with 31,010,000 and 159,780,000, found by Winslow, Greenburg, and Greenberg in two abrasive factories. The actual health hazard involved in sand blasting, with no protection at all, would be about equivalent to that actually existing in the abrasive factories in question. The discomfort due to the larger particles present would, however, prevent any such complete exposure in practice.

Efficiency of respirator as a means of protection against the dust in the sand-blasting cabinet.—Our next step was to determine the efficiency of the respirator (described above on p. 522) supplied to the workers in the plant. The sponge in the respirator was thoroughly

wetted and then squeezed free of excess water before using. Eight tests were made of this device on three different occasions and the results are presented in Table II. The second half of Table II includes three examinations of the normal air of the cabinet (already cited in Table I), which were made as direct controls at the time that the respirator studies were conducted.

TABLE II.—*Dust content of air of sand-blasting cabinet.*

Sample number.	After aspiration through respirator.			With no protection.			
	Number of particles per cubic foot of air.		Weight of total dust, milligrams per cubic foot of air.	Sample number.	Number of particles per cubic foot of air.		Weight of total dust, milligrams per cubic foot of air.
	1 standard unit.	¼ standard unit.			1 standard unit.	¼ standard unit.	
7251	25,000	1,370,000	0.19	7253	1,025,000	29,200,000	12.43
7252	105,000	4,355,000	2.86				
8061	20,000	6,055,000	.45	8064	4,000,000	82,000,000	27.20
8062	24,000	5,730,000	.37				
8063		7,070,000	.90				
8261	120,000	5,840,000	1.64	8265	2,266,000	37,000,000	18.53
8262	67,000	2,870,000	1.71				
8264	200,000	3,100,000	1.93				
Average	70,000	4,549,000	1.26		2,430,000	49,400,000	19.39

It should be noted that the experimental results obtained with the respirator were somewhat more favorable than those which could be expected in practice, since the respirator fitted our sampling funnel much more closely than it would be likely to fit the face of a worker. They should be comparable in this respect with the results obtained by the South African Commission, but not with those reported by Schablowski.

We can best judge of the efficiency of protective devices used in a given process by the dust content of the air actually respired by the worker. From this standpoint it will be evident that while the respirator alone does produce a remarkable reduction in dust content (from an average of 49,400,000 ¼ standard unit particles to 4,549,000 such particles per cubic foot), yet the final result (varying from 1 to 7 million and averaging 4,549,000 ¼ standard unit particles) can not be considered at all adequate for the protection of the worker. The dust content of the air after passing through the tightly attached respirator was still nearly as high as the values obtained in the worst industrial environments previously studied, with the exception of those reported for abrasive factories.

The respirator studied by us removed about 92 per cent of the dust present by count and 97 per cent by weight. These results on a count basis compare with the best of those obtained by Schablowski and the results by weight are much better than those reported by

the South African Commission. The conditions are not comparable, however, in view of the different dusts with which the respirators had to deal in the two cases. The dust content of the air of the South African mines, even after blasting, was only from 1.2 to 1.8 milligrams per cubic foot as against 12.4 to 27.2 milligrams in our case. The larger the amount of dust present in the air (and the larger the individual particles), the greater will be the per cent purification. Weight determinations are in any case of little value since the larger particles, of least sanitary significance, will be the ones most readily removed by any filtering device. The South African study includes only weights, but it is the count of small ($\frac{1}{4}$ standard unit) particles which is really significant, and it is on this point that we shall lay stress in discussing our results.

Efficiency of respirator and helmet in combination.—Our second problem was to determine the efficiency of the respirator combined with the helmet as used in actual practice at the plant. Samples for this purpose were taken, as described previously, by placing the sampling tube and funnel, with the respirator attached, inside the helmet supported on a table in the sand-blast cabinet. Nine tests of this sort were made on three different occasions, and the results are presented in Table III with three control tests of normal air taken at the same time.

TABLE III.—*Dust content of air of sand-blasting cabinet.*

After aspiration through respirator and helmet.				With no protection.			
Sample No.	Number of particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot of air.	Sample No.	Number of particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot of air.
	One standard unit.	One-fourth standard unit.			One standard unit.	One-fourth standard unit.	
8281	15,000	615,000	0.10	8284	467,000	15,000,000	37.95
8282	11,000	369,000	.15				
8283	12,000	504,000	.11				
9031	22,000	2,740,000	.04	9034	4,000,000	80,000,000	53.70
9032	32,000	3,260,000	.31				
9033	17,000	1,950,000	.09				
9051	107,000	4,280,000	1.46	9054	10,900,000	80,000,000	80.40
9052	65,000	3,000,000	.50				
9053	43,000	4,480,000	.92				
Average	36,000	2,355,000	.41		5,122,000	58,330,000	57.35

The dust content of the air of the cabinet at the time these tests were made varied between 15 and 80 million and averaged 58,330,000 one-fourth standard unit particles per cubic foot, while the air after passing through the helmet and respirator contained between 369,000 and 4,480,000 such particles and averaged 2,355,000. The results are distinctly better than those obtained with the respirator alone. The counts obtained are, however, far in excess of the limits which can be considered permissible for safety.

In connection with some of our later work we made 10 additional examinations of cabinet air after passing through the helmet and respirator. These results are presented in the second half of Table IV and check the results in Table III in a very satisfactory manner, the average number of one-fourth standard unit particles in this case being 1,770,000.

It appears evident from these observations that the helmet and respirator provided in the plant studied, when used without positive air pressure, do not adequately protect the worker against the existing dust hazard.

Efficiency of respirator and helmet provided with positive air pressure.—In view of the failure of the helmet and respirator to produce an adequate removal of dust, as operated above, we next proceeded to determine the efficiency of the apparatus when operated (as it was designed to be operated) with a constant air supply to the interior of the helmet.

The sampling tube, with respirator in place, was set inside the helmet and to the ¼-inch inlet at the top of the helmet was attached an air line delivering air through a flow meter, in the form of a constricted tube (see Fig. 7), described on page 528. Since the Palmer apparatus, during the period of sampling, was removing air from the interior of the helmet at a rate of 2 cubic feet per minute, it was necessary to supply air in excess of this amount in order to preserve a condition of positive pressure within the helmet. We therefore adjusted the valve on the air line so that the amount of air actually delivered to the helmet was in the neighborhood of 3 cubic feet per minute (ranging from 2.3 to 3.7 cubic feet per minute). The results of 19 such observations on 5 different occasions are shown in Table IV, with 10 control examinations of air collected with the helmet and respirator in place but without positive air supply.

It will be noted by reference to Table IV that air collected in this way (after passing through helmet and respirator) with no positive air supply, contained from 545,000 to 3,899,000 one-fourth standard unit particles, and averaged 1,770,000 such particles per cubic foot. On the other hand, the dust content of air sampled in the same manner but with an average air supply of 2.9 cubic feet per minute to the interior of the helmet, ranged from 18,000 to 329,000 one-fourth standard unit particles and averaged only 151,000 such particles per cubic foot.

TABLE IV.—*Dust content of air of sand-blasting cabinet after aspiration through helmet and respirator.*

With positive air pressure.					Without positive air pressure.			
Sample number.	Fresh air supply, cubic feet per minute.	Number of dust particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot of air.	Sample number.	Number of dust particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot of air.
		1 standard unit.	¼ standard unit.			1 standard unit.	¼ standard unit.	
1021	2.9	1,000	328,000	0.03	1023	8,000	974,000	0.03
1022	3.0	1,000	73,000	.01	1024	6,000	1,224,000	.06
1025	2.8		131,000	.02				
1071	2.7	1,000	25,000	.03	1072	5,000	545,000	.06
1073	2.6	6,000	18,000	.02	1075	9,000	945,000	.16
1074	2.6	2,000	74,000	.02				
1091	3.5		113,000	.03	1092	6,000	3,899,000	.07
1093	3.7		258,000	.06	1095	6,000	2,144,000	.10
1094	3.5	2,000	102,000	.03				
1096	3.4	1,000	207,000	.03				
10151	2.6	1,000	163,000	.09	10152	9,000	1,648,000	.07
10153	2.7	2,000	228,000	.02	10155	3,000	976,000	.07
10154	2.7	2,000	141,000	.01				
10156	2.7	1,000	322,000	.01				
10171	2.3	2,000	93,000	.02	10172	10,000	1,613,000	.06
10173	2.6	2,000	123,000	.01	10176	29,000	3,731,000	.14
10174	2.8	1,000	63,000	.01				
10175	2.3	3,000	71,000	.02				
10177	3.0	7,000	329,000	.05				
Average	2.9	2,000	151,000	.03		9,000	1,770,000	.08

These results are remarkably satisfactory. In a previous study (Public Health Reports, Mar. 7, 1919, p. 440) we have reported results obtained in a polishing shop equipped with an excellent exhaust system. In the air of this shop we found counts of one-fourth standard unit particles ranging from 22,200 to 854,000 and, averaging about 200,000 per cubic foot, and we suggested as a standard for such shops that the number of such particles should be kept generally below 300,000 per cubic foot and should not average over 200,000. It is most encouraging to find that even in a sand blast cabinet this degree of purity can be attained by the use of a respirator and helmet with positive air pressure.

From the standpoint of the weight of dust the results are equally satisfactory. We recommended as a standard for polishing shops that the weight of dust should generally be kept below 0.06 milligram per cubic foot, and should not average over 0.03 milligram; while the Phthisis Prevention Commission in South Africa and Higgins and Lanza in their study of the Joplin mines suggested limiting values of 0.14 milligram and 0.28 milligram, respectively, for mine air. The air of the sand blast cabinet after passing through the helmet provided with positive air pressure, and thence through the respirator, contained from 0.01 to 0.09 milligram per cubic foot, and averaged only 0.03 milligram per cubic foot of air.

Efficiency of helmet provided with positive air pressure but without the use of the respirator.—The results reported above were so encouraging, and indicated so clearly the value of positive air pressure in

excluding dust from the helmet, that it seemed of interest to determine the efficiency of the helmet alone, provided with positive air pressure but without the use of the respirator. We therefore set the apparatus up as before but without the respirator and, on two different occasions, collected the dust from 10 samples of air in this way, with three control samples in which the respirator was present. The air supply to the interior of the helmet was about the same as before, ranging from 2.4 cubic feet to 3.1 cubic feet and averaging 2.7 cubic feet per minute. The results of this study are presented in Table V.

TABLE V.—*Dust content of air of sand-blast cabinet after aspiration through helmet provided with positive air pressure.*

No respirator in use.					Respirator in use.				
Sample number.	Fresh air, cubic feet per minute.	Number of dust particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot.	Sample number	Fresh air, cubic feet per minute.	Number of dust particles per cubic foot of air.		Weight of total dust, mgs. per cubic foot of air.
		1 standard unit.	¼ standard unit.				1 standard unit.	¼ standard unit.	
10201	2.4	5,000	212,000	0.04	10202	2.4	5,000	200,000	0.01
10203	2.6	5,000	185,000	.08	10206	3.0	5,000	190,000	.04
10204	3.0	2,000	210,000	.01					
10205	3.0	3,000	331,000	.02					
10207	3.1	3,000	321,000	.03					
10291	2.5	3,000	355,000	.05	10292	2.6		184,000	.01
10293	2.4	8,000	238,000	.04					
10294	2.4	8,000	1,529,000	.07					
10295	2.6	2,000	181,000	.04					
10296	2.6	4,000	118,000	.03					
Average	2.7	4,000	368,000	0.04		2.7	3,000	191,000	0.02

The results obtained with air pressure in the helmet supplemented by the use of the respirator (presented in the right-hand half of Table V) correspond closely with those previously discussed (left-hand half of Table IV). The results obtained with the helmet provided with air pressure but with no respirator (left half of Table V) were not quite so good as those obtained with the use of the respirator, but the difference is comparatively slight. The one-fourth standard unit counts without the respirator ranged from 118,000 to 355,000, except for one count of 1,529,000, and the average, including this aberrant count, was 368,000 one-fourth standard unit particles per cubic foot. If the one exceptional count of sample 10294 were excluded the average for the group would be only 239,000 one-fourth standard unit particles per cubic foot. The weights obtained in this way without the respirator ranged from 0.01 to 0.08 milligrams per cubic foot, and averaged 0.04 milligrams per cubic foot.

The values obtained are very close to those we have recommended as ideal for polishing shops and are far below the standards set by the South African Commission and by Higgins and Lanza for mine air.

These results appear to us to be of considerable general interest as indicating the possibility of excluding dust from the respiratory tract of the worker by maintaining a positive air pressure in a comparatively impermeable inclosure about the head rather than by attempting to filter the incoming air through a close-grain respirator. In processes where the workman must move about over a wide area such a method of protection might not be feasible; but in the sandblasting cabinet it is altogether practical to use positive air pressure. It seems essential to use such air pressure whether the respirator is worn or not; and while we should not feel justified in recommending the abandonment of the respirator (in view of the better results obtained by its use in combination with the air-pressure helmet) it is satisfactory to know that if workers decline to wear the uncomfortable "muzzle" they will still be insured a very high degree of protection by the use of the air-pressure helmet alone. It should be remembered, too, that results obtained in our studies as to the efficiency of the helmet are entirely typical of those to be expected in practice, while our results on the respirator are unduly favorable because of the respirator fitted our sampling funnel more tightly than it would fit the face of the operator in practice.

Summary and Practical Conclusions in Regard to the Protection of Sand-Blast Operators.

The general average results of all our determinations are presented for comparison in Table VI.

TABLE VI.—*General summary of average results.*

	Number of samples.	Average dust content. One-fourth standard unit particles per cubic foot of air.	Average dust content. Total dust, mgs., per cubic foot of air.	For complete data see—
Air of cabinet	10	60,880,000	55.29	Table I.
Air passed through respirator alone	8	4,549,000	1.26	Table II.
Air passed through helmet and respirator	19	2,047,000	.24	Tables III, IV.
Air passed through helmet with positive air pressure	10	368,000	.04	Table V.
Air passed through helmet and respirator with positive air pressure.	22	156,000	.03	Tables IV, V.

It is evident that the normal air of the sand-blast cabinet studied contains an enormous number of small dust particles—a number larger than has been previously reported from any source except the air of an abrasive factory. The weight of dust is far in excess of any result previously recorded. Since the dust in this case is chiefly composed of particles of crystalline silica, a dust known to cause distinctive changes in the lung tissue which predispose to pulmonary

tuberculosis, it is evident that the workers in the sand-blasting industry are exposed to a serious hazard from which they should be protected by the most effective possible means.

The figures presented in the second and third lines of Table VI indicate that while the respirator alone, and the respirator combined with the helmet, effect a substantial removal of the finer dust particles, the air which passes through the protective apparatus in the absence of positive air pressure within the helmet is still laden with an amount of fine dust far in excess of the limits necessary for the protection of the worker. The dust content of the air which passes the helmet and respirator (without positive air pressure), amounting to 2,047,000 one-fourth standard unit particles per cubic foot, is about what would be found in a polishing shop or tumbling room of very low grade and equipped with what would be recognized as a wholly inadequate exhaust system.

The introduction of positive air pressure within the helmet effected a radical change in conditions. Even without the respirator the helmet alone, when provided with a supply of 2 to 3 cubic feet of air per minute, reduced the dust content of the air from many millions to a few hundred thousands of particles (average 368,000 one-fourth standard unit particles per cubic foot). This is a striking demonstration of the results which may be obtained by the use of a comparatively impermeable head covering provided with sufficient internal air pressure to produce an outward air flow, a procedure which in many industrial processes may supplement or replace protection devices based on the filtration principle.

The helmet provided with positive air pressure does not, however, without the respirator, produce an absolutely satisfactory degree of protection. Out of 10 samples collected in this way, 4 showed counts of over 300,000 one-fourth standard unit particles per cubic foot, and one of these had a count of over 1,500,000. With the helmet provided with positive air pressure plus the respirator, on the other hand, results of the most satisfactory nature were obtained. Out of 22 samples of air which had passed through these combined protective devices, only three showed counts of over 300,000 one-fourth standard unit particles per cubic foot, while not one exceeded 330,000 such particles. The average for the whole group was 156,000 one-fourth standard unit particles per cubic foot, a result which must be considered a really remarkable one. It is probable, however, that the 156,000 dust particles passing the helmet and respirator include a larger proportion of hard, siliceous, and, therefore, dangerous particles than would be found in a similar dust count in an ordinary room. Our studies indicate that the dust in the air of the sand-blast cabinet is over 99 per cent inorganic matter, while the dust collected from air which had passed through the helmet with positive air pressure gave an average for 22 samples of only 80 per cent inorganic material.

This proportion is higher than that characteristic of normal air and suggests that minute traces of siliceous dust are still present. The amount is so small, however, that the air actually breathed by the worker is of a character comparable to that found in a grinding shop equipped with the best known exhaust devices, and from a practical standpoint the results must be considered entirely satisfactory.

We would therefore recommend that where the nature of the operation is such as to require the presence of workers within the sand-blasting cabinets of the types studied, all such workers should be protected by helmets provided with positive air pressure and with respirators of the general type described above; and under such conditions it may be assumed that substantially complete protection will be secured.

In regard to the amount of air to be supplied to the helmet in practice, it should be noted that we used, on the average, somewhat less than 3 cubic feet per minute, while the Palmer apparatus was constantly removing 2 cubic feet per minute. In other words, the pressure at the front window of the helmet was produced by an excess of air supply over air exhaust through the Palmer apparatus of less than 1 cubic foot per minute. In practice it would only be necessary to maintain a corresponding excess of air supply over the amount withdrawn from the helmet during inspiration. Assuming that for the type of physical effort required in sand blasting each inspiration removes 90 cubic inches of air in a period of 1.5 seconds the draft upon the air in the helmet, during the inspiration period, would be at the rate of approximately 2 cubic feet per minute. A gross air supply to the helmet of 2.5 to 3 cubic feet per minute should therefore prove ample to maintain satisfactory conditions in practice.

The solution of the odor problem (which, as noted above, has proved troublesome in the plant where our studies were made) has proved comparatively simple. We found that only when large quantities of air were allowed to enter the helmet was the odor of oil noticeable. With the air supply to the helmet reduced to 3 cubic feet per minute, we were ourselves unable to detect any odor in the air supplied. If trouble of this kind should be experienced, there are on the market simple and inexpensive air filters which may be placed in the air line to remove any impurities present. We experimented with one such filtering device, made by the La France Fire Engine Co., of Elmira. N. Y., and found that the helmet supplied with air passed through this filter could be worn for over half an hour without the slightest inconvenience due to odor. On actual test an amount of oil which would equal two or three drops collected in the filter during such a period. In order to avoid possible complaints the inclusion of such a filter in the air line would seem to be desirable. The use of a small impeller type blower which does not use lubricating oil internally for the fresh-air supply would of course solve this difficulty completely.

The introduction of $2\frac{1}{2}$ to 3 cubic feet of air per minute through a $\frac{1}{4}$-inch hole at the top of the helmet would produce an uncomfortable draft on the top of the uncovered head, particularly in cold weather. The operators in using the apparatus as recommended by us wore their caps and in testing it ourselves we placed a folded handkerchief on the top of the head. It would seem desirable, however, to construct the helmet with a deflector plate under the air inlet so as to distribute the air more evenly and avoid the necessity for other protection. It would also be well to provide an air chamber equipped with a small heating coil to temper the incoming air in cold weather.

Finally, there are a few minor points in construction which will contribute materially to the success of such protective devices as those described. The tubing connecting the air line to the helmet should be of light weight so as to avoid a drag on the head of the operator, and it should be connected to the supply pipe overhead and near the center of the chamber so that its length may be as short as possible. We would recommend that about 2 feet of the tubing should be permanently connected to the helmet and equipped with a connecting joint (which might be merely a 2-inch section of brass tubing) so that the worker could enter the chamber fully equipped and make his air-line connection without removing his helmet. It would seem advisable to provide no air valve within reach of the worker, but to keep the air control under the supervision of the foreman. The air valve should be set to deliver 2.5 to 3.0 cubic feet of air per minute, and this air supply should be continuously maintained during working hours. The additional cost required to maintain a continuous air supply would be a minor item compared with the danger arising should individual workers fail to turn on the air supply.

With the type of installation described above we believe that the worker in a sand-blasting cabinet will be effectively safeguarded against the dust hazard incident to his employment.

ANTIMALARIAL WORK IN DALLAS, TEX.

By Leslie C. Frank, Director of Public Health, and Frank R. Shaw, City Sanitarian.

Malaria-control activities in the city of Dallas, Tex., were started May 9, 1916, under the general supervision of Mr. Charles Saville, Director of Public Health, and under the immediate direction of Mr. H. W. Van Hovenberg, Chief of the Division of Sanitation, and have been continued throughout each season to the present year.

The first year's work consisted of the initial brushing, channeling, and training of creeks and natural water courses, the draining of pools of water, and oil operations for the prevention of mosquito breeding where it was not otherwise prevented. An educational campaign was conducted so as to mold public opinion and secure the best possible cooperation.